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ABSTRACT

In Zimbabwe, university students continue to have problems with scientific communication despite the fact that English is a widely-used second language and students have received most formal science instruction in English. However, the problems differ from those of both students of English as a foreign language and students studying their first language. Problems are more commonly performance than competence errors, and students' language skills need to be developed in tandem with their cognitive skills. Students exhibit a variety of problems in expressing scientific propositions appropriately. They frequently make propositions that are inaccurate because they are expressed with an inappropriate degree of generalization, usually overgeneralizing. Students may overqualify a theory or use unnecessary conditionals, suggesting lack of confidence in some generalizations. They may also have difficulty expressing indefinite reference in a generalization or expressing the relationship between theoretical predictions and experimental results. Some of the problems are primarily linguistic, but many relate to the requirements of scientific discourse as it embodies scientific method. English for science and technology must be taught as an extension of science education. (MSE)

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TEACHING COMMUNICATION SKILLS TO SCIENCE STUDENTS AT TERTIARY LEVEL IN ZIMBABWE: teaching 'scientific discourse' or 'textualisation'?

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Background

Some years ago, Widdowson, writing about teaching English for Science and Technology, made a distinction between 'scientific *discourse*' and scientific '*textualisation*'. He suggested that 'scientific *discourse* is a universal mode of communicating, or universal rhetoric, which is realised by scientific *text* in different languages by the process of *textualisation*' (Widdowson 1979: 52). His assumption was that students have acquired basic scientific knowledge through their first language, and that 'the English teacher's task is not to develop this knowledge but to demonstrate how it is realised through the medium of a different language' (ibid: 44). He pointed out that the student's knowledge of universal scientific *discourse* can be drawn upon to support their development of an alternative *textualisation*. This is clearly true in many language teaching situations throughout the world, such as those in which students proceed for post-graduate training in a foreign country. However, in a country like Zimbabwe, where English is a widely-used Second Language and is the medium of instruction thoughout most of the school system, students have received all their formal scientific education through English. These students still have problems of scientific communication when they enter university, but these are different from those of EFL students. They are likely to occupy an intermediate position between those of EFL students, and the developmental needs of students studying in their first language.

Students in Zimbabwe come to university with a fairly high level of fluency in English. However, they still exhibit formal errors, and language teachers are frequently asked to provide remedial services to eliminate these. Most of us working in the field, however, do not believe that this would answer the greatest needs of the students, since what we believe we see in student work is a fairly high density of *performance* errors, brought about by lack of confidence in demanding situations, rather than errors of *competence*. Students in Zimbabwe arrive at university from a school background where, for various reasons, they have relied to a large extent on rote-learning. University demands of them that they develop much more independent study strategies, and this naturally includes the development of their linguistic skills in the service of their own learning. The language teacher, therefore, needs to support the students in their development of independent use of the language as 'an instrument of thought', to quote Bruner (1975). The students need to develop their linguistic skills in tandem with their cognitive skills.

This means that as language teachers we are concerned with the new demands made on the students' linguistic resources. These are not so very different from those faced by science students for whom English is a first

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language, but the difficulties appear to be intensified when education is in a second language. J.C. Richards has written of 'the addition of higher lects from the lectal continuum for specialized language functions', and commented that this is 'a *normal*, rather than abnormal or unusual situation', although not always recognised as such (Richards 1982: 242). Ballard and Clanchy have pointed out that 'cognitive competence' in a particular academic discipline cannot be separated from 'linguistic competence' in the discipline (Ballard & Clanchy 1988: 17). This suggests that the task of the language teacher in the situation I have outlined is indeed to help students acquire discourse skills in their area of study - in my case scientific discourse skills - albeit in close co-operation with the relevant subject staff. Our task involves discovering the main problems experienced by students in achieving the required fluency in scientific discourse, and offering help in those areas.

What does this mean? Clearly it involves an exploration with students of the scientific uses of such rhetorical functions as description, explanation, generalisation. However, in this paper I wish to focus on characteristics of scientific discourse at sentential level, and the problems they pose for students. Such an approach is likely to involve the language teacher in an examination with students both of the surface characteristics of scientific text, and the underlying purposes of these characteristics in scientific discourse. In other words, the language teacher will be concerned with the development of both 'universal scientific discourse' and 'textualisation' in the specific language, and will find it necessary to make explicit the interaction between them.

Hunston (1987) points out the importance in scientific discourse of the *status* of propositions in terms of their acceptedness and of their generalisability. Her emphasis on these points corresponds with problems which I have observed in student writing. At first-year university level, students are concerned mainly with accepted scientific facts - 'received knowledge', in Hunston's classification. When memorising such facts, or using them to solve contextualised problems, students appear to have few difficulties. However, when they are required to make independent statements involving their recently acquired knowledge, they produce scientifically inaccurate propositions whose shortcomings frequently relate to appropriate levels of acceptedness and generalisation. There are inevitable problems here in perceiving whether the weakness is due to inadequate scientific understanding or to inadequate expression. However, the language teacher can tackle the issues of expression with the intention of focusing students' attention on conceptual areas where the interaction between ideas and their expression requires particular care.

Data collected over several years of teaching first-year science undergraduates at the University of Zimbabwe suggests that these students exhibit a variety of problems in expressing scientific propositions in a manner which conveys their scientific status appropriately. I shall present examples to demonstrate the types of problems which arise, and suggest reasons for these problems.

Levels of generalisation

I shall look first at problems with levels of generalisation. Students frequently make propositions which are scientifically inaccurate because they are expressed with an inappropriate degree of generalisation. The most typical problem is that posed by an unqualified general statement:

1. When an experiment is performed under different conditions, different products are obtained.
2. The room temperature determines the experimental results.
3. When a reaction is carried out in the cold the formation of products is minimised.

All these examples illustrate the tendency students show to *over-generalise*, in contexts where much greater precision is required, a precision which would be achieved by qualification and/or modalisation. Students at this stage are almost certainly aware that the results of some experiments are only *likely* to be changed by a change in conditions, and that temperature is only one factor involved in the determination of results. Yet they produce these inaccurate propositions presumably because of a lack of awareness of the need to qualify or modalise generalisations appropriately in scientific discourse. It seems likely that the problem here is a developmental one, relating both to cognitive and linguistic issues. Students may have difficulty in assessing the overall status of a proposition, taking into account factors outside the writer's immediate focus. Equally, they may not recognise the need for much greater attention to the semantic status of a proposition in the scientific register than in less formal and particularly colloquial language. Overgeneralisation is frequently acceptable in informal discourse, since the context prevents misinterpretation. Students need to develop the ability to produce context-free discourse, and the cognitive effort which is necessary to determine appropriacy.

Examples (2) and (3) also illustrate a different problem of expression which also results in an overgeneralised proposition. This is the use of words inappropriate in their degree of gradability. In each example the student has selected words - 'determines', 'is minimised' - which convey absolute meaning, when words conveying relative meaning - e.g. 'influences', 'is reduced' - would be more appropriate to the status of the proposition. This is a common problem with both semi-technical words, such as those discussed, but also with such common qualifiers as 'most' and 'many', 'same' and 'similar'.

4. Most angiosperms, for example the guava tree, produce edible fruits.
5. Elements in the same group of the periodic table have the same chemical properties.

Example (5) produces a scientific statement which amounts to nonsense, since the unqualified use of the absolute term 'same' removes any distinguishing differences between elements. Example (4) shows the problem of selecting a word which, while not absolute, is too far along the

gradability scale towards the absolute. The proposition is simply untrue statistically.

It is interesting to note that converse problems arise, producing undergeneralised propositions:

6. Elements in a particular group in a Periodic table have almost similar chemical properties.

7. Most of the air we exhale is rich in carbon dioxide.

8. Photosynthesizing is a characteristic property of many green plants.

In example (6) the student's uncertainty about the use of identity and similarity terms has led to the introduction of an unnecessary qualifier. In example (7) the use of 'most' is inappropriate, since the unmodified form 'the air' would have been accurate. Similarly, the use of 'many' in example (8) is scientifically inaccurate, since here an absolute statement is required.

In considering the reasons for these problems, a complex interaction between cognitive and linguistic factors appears. It seems likely that students have genuine problems in establishing the status of a proposition. A possible cause for overgeneralisation is the focusing of attention on one aspect of a subject for learning purposes: angiosperms are characterised as fruit-bearing, and the student overgeneralises from the example of familiar edible fruit; groups in the periodic table are related to the properties of elements, and the differentiating characteristics between elements in the group may be temporarily overlooked. Undergeneralisation, on the other hand, may well be caused by lack of confidence in the extent of the student's knowledge, leading to hedging to cover against unknown exceptions. Linguistically, it appears that some of these errors derive from unfamiliarity with the precise denotation of words, especially such semi-technical words as 'determine' or 'minimise'. The student is aware of their appropriacy to the scientific register, but uses them inappropriately due to unfamiliarity with the absolute nature of their meaning. This explanation cannot, however, be applied to the misuse of common words such as 'most' and 'same'. Here the origin of the problem is likely to be the informal use of such words in the local variety of English. The substitution of 'most' for Standard English 'many' is extremely common in Zimbabwean English. The explanation almost certainly lies in the lexicon of the dominant first languages in Zimbabwe, which do not make this precise distinction. In any one instance it is difficult to ascertain the balance of linguistic and cognitive factors, and it is likely that linguistic habits reinforce cognitive difficulties.

A final aspect of student difficulty with achieving an appropriate level of generalisation is concerned with expressing exceptions to generalisations. This is perhaps less serious, since it does not produce true scientific inaccuracy, but is nonetheless irritating and possibly confusing to the reader. Students tend to express the generalisation as an

absolute proposition, and then add the exceptions as if as an afterthought.

(9) All heterotrophs show direct dependence on autotrophs although some like carnivores (e.g. lions) show indirect dependence.

Although the meaning is clearly retrievable, this example suggests that the student is extremely uncertain in handling levels of classification (dependence, subdivided into direct and indirect), and any discussion of such problems with students would need to look at the level of generalisation of statements, as well as surface linguistic features such as the use of 'with the exception of'.

It appears, then, that students experience problems, both cognitive and linguistic, in the production of scientific propositions of the appropriate level of generality.

Levels of acceptedness

Further problems arise in relation to the level of acceptedness of a proposition. As mentioned earlier, students at first-year university level are operating almost entirely with accepted facts, and it might be expected that they would have little difficulty in selecting the correct verb forms for expressing them. However, problems do arise with surprising frequency when students are making generalisations concerned with scientific theory.

(10) Atoms are supposed to be composed of a nucleus in the centre surrounded by electron 'shells'.

(11) Green plants contain chlorophyll, therefore they are expected to manufacture food by the process of photosynthesis.

(12) A knowledge of the structure of molecules helps to explain why some substances are very unreactive. An example of the latter case has been found to be phenol which does not react easily with mild reactants. The size of the molecule is also said to play a part in determining the speed of a reaction.

These examples show lack of confidence in making statements of accepted scientific fact. Example (10) suggests that the student has problems appreciating the status of a theoretical statement which he/she feels is not easily verified empirically, and has used 'supposed to' as a kind of modal verb, marking uncertainty about the status of abstract propositions. Example (11) shows weakness in expressing the connection between observable fact (green plants contain chlorophyll) and the less readily observable knowledge of which this is evidence. Again, a 'quasi-modal' is employed, indicating uncertainty in how to express accepted deduction. Example (12) seems to be an example of a student who is familiar with typical verb forms found in scientific discourse, but uses them inappropriately. 'Has been found to be' would more appropriately be used in the reporting of *recent* experimental work, while 'is said to' expresses a considerably lower degree of acceptedness than is appropriate for the

proposition being made. Once again, there appears to be an interaction between cognitive difficulties in achieving confidence with abstract scientific theories and their relations to observable evidence and difficulties with appropriate expression of the status of such theories.

A related problem in the expression of scientific fact is the widespread tendency to use a conditional verb form in a generalisation.

(13) When one inhales oxygen, his diaphragm would be dome shaped.

(14) Radioactivity is a spontaneous chemical process which a chemical substance may undergo producing another different substance. The substance which undergoes the process would be unstable, thus the product would be more stable than the original substance.

(15) After fertilisation, the zygote, formed from the two haploid gametes of parents, would contain half the genetic information from each parent.

In all these examples, the students appear to feel that, because the statements are generalisations, not referring to specific events in time, there is an element of uncertainty which renders the conditional form necessary. They appear to lack the confidence to use the generalising present tense or the predictive 'will'. However, it is possible that these uses of the conditional, which deviate from Standard English usage, derive from the local variety of English. Although no systematic description of Zimbabwean English has yet been completed, evidence is building up that the use of the conditional in predictions and generalisations is extremely common.

Related to these problems is the difficulty experienced by students in expressing indefinite reference in a generalisation. Definitions and other general statements frequently require reference to an individual but unspecific concrete example, and students find this extremely difficult to express appropriately.

(16) Bond energy is the amount of energy which was involved in forming that particular bond.

(17) Adsorption is the sticking of molecules of a substance onto a certain substance, e.g. adsorption of a substrate by a catalyst, whereas absorption is to draw in some molecules of a liquid or gas by a certain medium, e.g. absorption of water by a plant root.

Example (16) is a clear instance of the situation described by Swales, where the participial form 'a given' is required to express the appropriate degree of generalisation. Swales points out that this usage specifies 'the "determiner range" of the NP as a means of qualifying a generalisation' and demonstrates how the expression is 'comparable but different in meaning to *a certain*' (Swales 1981: 48-9). Failure to achieve this precise meaning results, as in example (16), in an inappropriate connection between generalisation and specific instance, as shown by the use of the past tense, as well as the phrase 'that particular bond'. Example (17) also shows difficulty in selecting specifying qualifiers. Here the use of 'a certain' is not appropriate, and such indefinite expression as 'one substance .... another substance' would have

expressed the idea more accurately, especially as it is supported by the correctly expressed specific examples. These problems, as Swales makes clear, are related to an aspect of scientific discourse which employs expression not commonly found in other registers of the language, since it expresses a level of generalisation rarely emphasised outside scientific discourse. Again, the problems appear to be both linguistic and cognitive, since students need to appreciate the *need* for indefinite reference as well as the typical scientific form of expressing it.

Finally, students experience difficulties in expressing the relationship between theoretical predictions and experimental results, particularly if the predictions are not exactly fulfilled.

(18) In a genetic experiment, 100 peas were grown and according to the genetics rules 75 plants were supposed to be tall but 70 plants were tall. This error was negligible.

(19) These neutrinos are supposed to be detectable on the earth's surface [to verify Bethe's theory] but as yet these neutrinos appeared to be 'missing'.

In example (18) the student clearly understands the concept of acceptable margin of error in experimental application of theory, but the use of the 'quasi-modal' 'supposed to' rather than 'predicted' weakens the expression. In example (19) the student has experienced great difficulty in expressing the relationship between observed evidence and not yet verified theory. In this case the problem may well have originated in the task, which is relatively unfamiliar at first-year level, of expressing propositions which have not yet acquired the status of accepted scientific fact.

Discussion

As has emerged in the discussion of individual examples of student scientific propositions, the problems in scientific expression shown by Zimbabwean first-year students appear to derive from an interaction between cognitive and linguistic factors. This is not surprising, since the students are simultaneously developing their scientific understanding, and being expected to express it independently in discourse in a second language at a higher lectal level than has been required of them previously. In particular, it is not surprising that many problems arise in the area of handling of generalisations, since students are likely to be in the process of developing their ability to formulate context-free propositions, and to subordinate concrete reality to theoretical possibility. Bruner (1975), drawing on both Inhelder and Piaget and Vygotsky , points out the crucial significance of this stage in language development. It is important that this interaction between cognitive and linguistic development is recognised, both by language teachers and by content subject lecturers, in order to avoid the tendency to attribute student weakness to linguistic inadequacy without consideration of wider educational issues. Some of the problems *are* predominantly linguistic, such as the semantic problem of lexical gradability, and the tendency to use the conditional form in generalisations and predictions. But many of the problems relate to the requirements of scientific discourse as it

embodies scientific method. Students need to appreciate the importance of such concepts as scope of generalisation, status of scientific proposition and the relationship between prediction and evidence.

Teaching approaches

How can these aims be achieved in teaching? I will mention briefly a few of my approaches, although I would not claim that they necessarily achieve their objectives.

Because of the need to integrate linguistic development and cognitive development in science, I consider it necessary to make an explicit connection between precision in scientific expression and scientific method. Language teachers are more likely to receive co-operation from students who, like ours, consider their general fluency in English adequate, if they are able to relate the syntactic and semantic issues presented to the scientific principles they embody. Therefore it is likely to be helpful to discuss with students the need for attention to scope of generalisation, status of propositions and similar scientific principles.

Zimbabwean students need to have their awareness of the need for precision in scientific discourse aroused, and this can be done quite successfully through discussion of examples of their own scientific writing. Students appear to enjoy looking for less obvious errors of scientific expression, and heated debates about scientific accuracy often develop, which are quite beyond my capacity to arbitrate! They appear to find the gradual realisation of the inaccurate implication of something they have written entertaining, and I trust this amusement assists in internalising the linguistic principle involved.

Some linguistic points can be taught explicitly. I spend time sensitising students to the nuances of gradability between words in specific semantic fields, and encourage them to produce their own examples of usage from their own study areas to test their understanding. (For example: What is a *unique* characteristic, or *unusual*, or *common*, or *universal*?).

Some syntactic points are introduced directly. For example, I attempt to demonstrate from examples the difference between 'a given' and 'a certain' or 'a particular'. I expect the students to study extracts of scientific text to explore the use or absence of modal verbs in generalisation and prediction.

These aspects of textualisation are fairly straightforward to teach. What is harder is to assist the students in developing confidence in their own ability to recognise and produce appropriate scientific discourse. Ultimately it can probably only be achieved through close co-operation and team-work with science lecturers, so that the balanced connection between cognitive and linguistic development in the discipline can be reached. At the University of Zimbabwe, therefore, we endeavour as much as possible to engage in collaborative work with content subject lecturers, in finding ways of ensuring that student learning takes place at a deep level, and is not restricted to surface rote-learning. To return to Widdowson's

discussion of teaching EST, we agree that 'EST.....must be conducted not as a separate operation but as an extension from science education' (Widdowson, op.cit. 47).

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